

TOPIC E –

ENVIRO CHEMISTRY

PART 4 – OZONE

DEPLETION

IB Chemistry

Topic E – Enviro

Hodder Ed - Talbot



E4 Ozone depletion - 1.5 hours

- E.4.1 Describe the formation and depletion of ozone in the stratosphere by natural processes. (2)
- E.4.2 List the ozone-depleting pollutants and their sources. (1)
- E.4.3 Discuss the alternatives to CFCs in terms of their properties. (3)



E4.1 – Ozone Formation and Depletion

- E.4.1 Describe the formation and depletion of ozone in the stratosphere by natural processes. (2)
- *Formation:*
 - $O_2 + uv \rightarrow 2O\bullet$
 - $O_2 + O\bullet \rightarrow O_3$
- *Depletion:*
 - $O_3 + uv \rightarrow O_2 + O\bullet$
 - $O_3 + O\bullet \rightarrow 2O_2$



E4.1 – Ozone Layer

- Ozone is a powerful oxidizing agent
- When formed in the air, it's considered a pollutant since it can reach concentrations harmful to humans and exist outside of the ozone layer
- Ozone is formed by the photochemical reactants that lead to smog
- The **Ozone layer** is considered “good” ozone as it absorbs harmful UV radiation which leads to skin cancer. Without the ozone layer, we could not have evolved



■ Major impacts to the ozone layer due to human activity can be seen at the polar regions

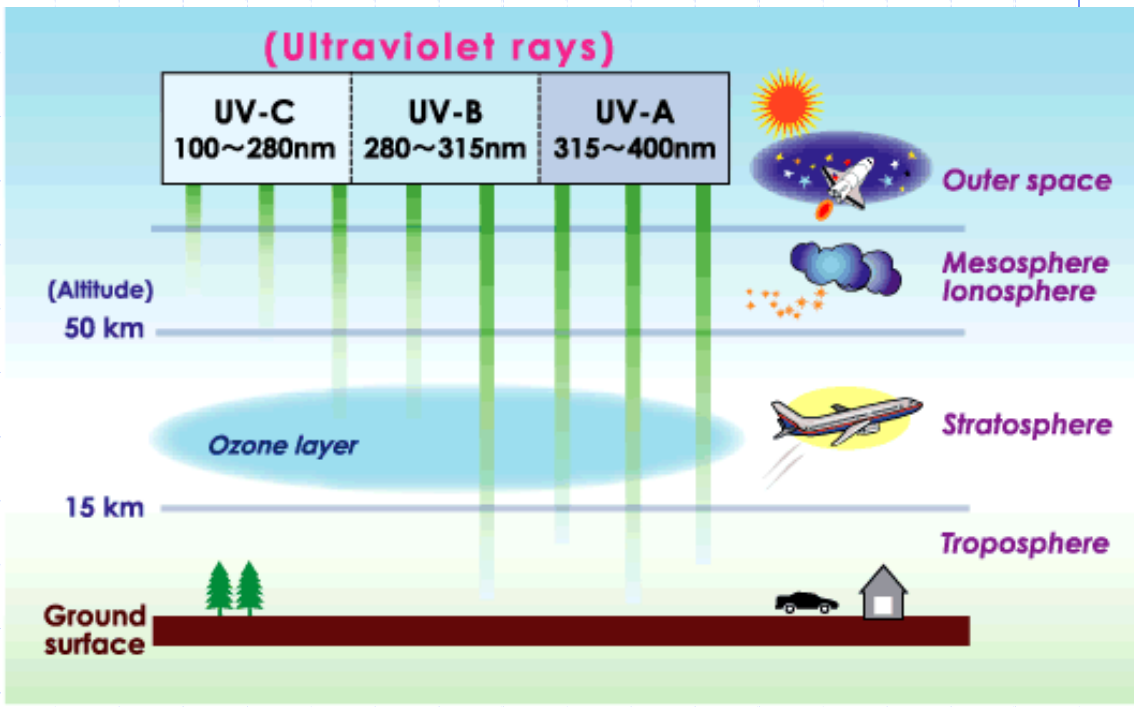
E4.1 – Stratospheric Ozone

- The stratosphere is the layer lying above the troposphere at altitudes around 12km(~39,000ft)-52 km.
- Over 90% of all ozone (O_3) found in stratosphere
- Exists even in ozone layer in $[O_3]$ of <5ppm
- In the stratosphere, the level of ozone is maintained by a cyclic series of processes, in which ozone is continuously **created** and **destroyed**
 - These processes involve the absorption of UV



E4.1 – UV Radiation

- UV region of the spectrum is divided into three regions:
- UVa: 320-400nm
 - Not harmful
 - Not blocked
- UVb: 280-320nm
 - Less Harmful
 - Less blocked
- UVC: 200-280nm
 - **HARMFUL**
 - blocked



Small changes in Ozone can lead to a significant rise in UVb , resulting in increased incidence of skin cancer



E4.1 – Ozone Formation and Depletion

- The processes of formation and depletion of ozone in the stratosphere is normal.
- The rates of formation and depletion are equal in “normal” circumstances
- This delicate balance must be maintained for the ozone to be effective
- Ozone Formation
 - From O_2 and UV energy
- Ozone Depletion
 - From O_3 and UV energy



E4.1 – Natural Ozone Formation

- Diatomic oxygen absorbs a photon with $\lambda < 242\text{nm}$ which is in the **UVc** region
 - $\text{O}_2 (+\text{UV } 242\text{nm}) \rightarrow \text{O}\bullet + \text{O}\bullet$
 - $\text{O}_2 + \text{O}\bullet + \text{M} \rightarrow \text{O}_3 + \text{M}$
 - M is used as a catalyst (third body) for the reaction. It carries away excess energy.



E4.1 – Natural Ozone Depletion

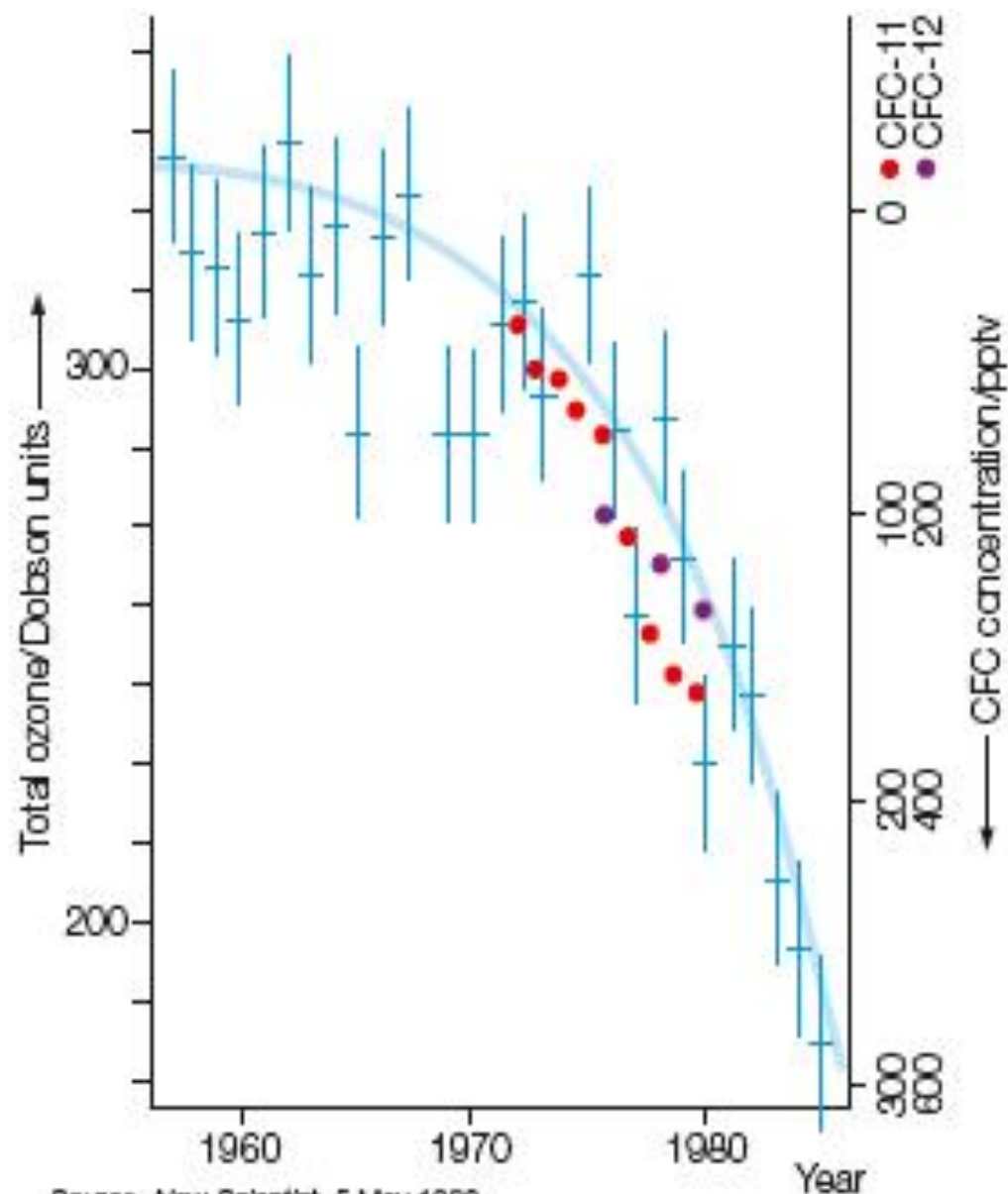
- The UV photon can cause an ozone molecule to dissociate into a diatomic oxygen as well.
- This process requires a photon $\lambda = 290-320\text{nm}$ which is the **UVb region**
 - $\text{O}_3 (+ \text{UV } 290-320\text{nm}) \rightarrow \text{O}_2 + \text{O}\bullet$
 - $\text{O}_3 + \text{O}\bullet \rightarrow 2\text{O}_2$
- These two processes (formation, depletion) lead to a steady concentration of ozone and **UVc** and **UVb** are largely filtered out in this process if the ideal!



E4.2 – Ozone-depleting Pollutants

- E.4.2 List the ozone-depleting pollutants and their sources. (1)
- *Examples include chlorofluorocarbons (CFCs) and oxides of nitrogen (NO_x).*
- In 1985, the British Antarctic Survey published research showing that the ozone concentration over Antarctica was lower than expected.
- This unexpected lowering of the ozone concentration became known as the **"hole"**
 - Suspected cause of the hole in the ozone was the use of CFC's





Source: *New Scientist*, 5 May 1988

Figure 25.12 Halley Bay: drop in mean total ozone correlated to incidence of CFCs

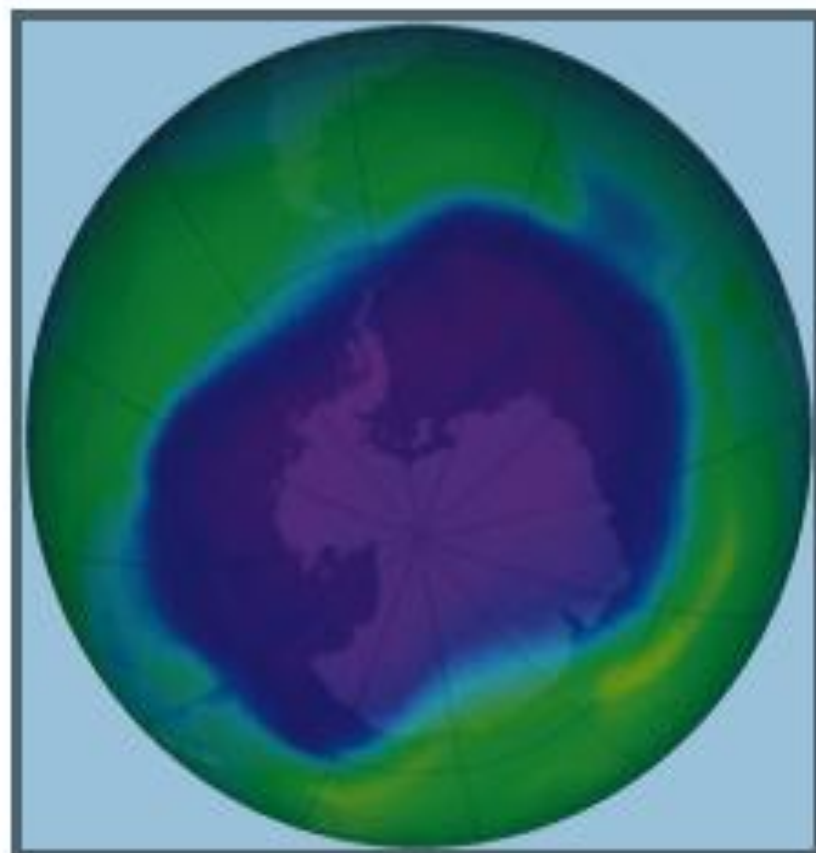


Figure 25.13 NASA image of the ozone hole in 2006 (blue and purple colours show where there is least ozone)

E4.2 – What are CFC's

- Chlorofluorocarbons (CFC's) were designed as propellants for aerosol sprays and as refrigerants
- These chemicals are volatile and chemically inert in the troposphere which is why they were used in aerosols as they didn't contaminate the liquid
- When released at ground level, they slowly mix throughout the troposphere. They remain unreactive in the upper troposphere since UV light that can illicit a reaction is absorbed by ozone
- Once the CFC's reach the stratosphere, they react with large amounts of radiation from the sun and produce chlorine radicals Cl•



E4.2 – Ozone Depletion (CFC's)

- When the CFC molecules eventually reach the stratosphere, they dissociate by UV radiation:
 - $\text{CFCl}_3 + \text{UV} \rightarrow \text{CFCl}_2\bullet + \text{Cl}\bullet$
 - ♦ (photodissociation of CFC-11)
 - $\text{CF}_2\text{Cl}_2 + \text{UV} \rightarrow \text{CF}_2\text{Cl}\bullet + \text{Cl}\bullet$
 - ♦ (photodissociation of CFC-12)
- A chain reaction is initiated in which $\text{Cl}\bullet$ destroy an ozone molecule, and are then regenerated in another reaction, allowing further depletion



E4.2 – Ozone Depletion (N_2O)

- Most nitrogen oxides formed in the troposphere are sufficiently reactive that are used up in chemical reactions, such as those which produce smog, or acid rain.
- BUT, N_2O (nitrous oxide), is relatively unreactive allowing it to rise to the atmosphere where it can combine with a $\text{O}\cdot$
 - $\text{O}\cdot + \text{N}_2\text{O} \rightarrow 2\text{NO}\cdot$
- NO participates in similar chain reactions to chlorine atoms, and so is regarded as a serious ozone-depleting pollutant as well



E4.3 – Alternatives to CFC's

- E.4.3 Discuss the alternatives to CFCs in terms of their properties. (3)
- *Alternatives include **hydrocarbons** (C_xH_y), **fluorocarbons** (FC's) and **hydrofluorocarbons** (HFCs).*
- *Include toxicity, flammability, the relative weakness of the C–Cl bond and the ability to absorb infrared radiation.*



E4.3 – CFC Alternative (HCFC's)

- The presence of weaker C-H bonds in the molecule affects the reactivity of the molecule.
 - CFC's exists as stable molecules til stratosphere
 - HCFC's react in troposphere by attack from OH•
 - The H-atom combines with OH• to form H₂O and the remainder of the molecule (CFCl₂•) is able to break down further and release water-soluble compounds into the atmosphere which can be removed by rain



E4.3 – CFC Alternative (HFC's)

- Hydrofluorocarbons (HFC's) are preferable to HCFC because they contain no chlorine.
- The C-F bond is much shorter than the C-Cl bond and is thus much stronger so UV photons carry insufficient energy to break the C-F bond.
- HFC's are broken down in the troposphere in a similar way to HCFC's, but the absence of chlorine means that HFC's have no tendency to deplete the ozone



E4.3 – CFC Alternative (C_xH_y 's)

- Mixtures of propane and butane have been marketed as alternatives to CFC's, especially in refrigeration and air conditioning applications
- Appliances must be carefully designed to minimize the possibility of the hydrocarbon being ignited, for example by an electrical spark.

